SURGICAL INFECTIONS
Volume 11, Number 3, 2010

DOI: 10.1089/sur.2010.021

Surgical Site Infection Prevention: How We Do It

Tjasa Hranjec, Brian R. Swenson, and Robert G. Sawyer

Abstract

Background: Efforts to prevent surgical site infection (SSI) employ methods that are valid scientifically, but each institution and each surgeon also incorporates methods believed to be useful although this has not been proved by clinical trials.

Methods: The surgical literature was reviewed, as were practices at the University of Virginia that the authors believe are of value for the prevention of SSI.

Results: Preventive antibiotics are established measures. A case can be made for increasing the dose in patients with a large body mass, and antibiotics probably should be re-administered during procedures lasting longer than 3 h. Chlorhexidine showers for the patient are not proven; however, they are inexpensive and of potential benefit. Hair removal is always done with clippers and in the operating room at the time of the procedure. No scientific case can be made specifically for using antiseptic at the surgical site before the incision. Keeping the blood glucose concentration and the core body temperature near normal probably are important, but how close to normal is unclear. Transfusion enhances SSI, but leukocyte reduction of transfused blood may be of benefit. Some evidence supports the value of antibacterial suture in preventing SSI.

Conclusions: Many proven and potentially valid methods are employed to prevent SSI. Coordinated and standardized protocols with good data collection can assist the multi-disciplinary efforts to reduce SSI within the unique practices of a given institution.

Surgical site infections (SSI) are the most common nosocomial infections in patients undergoing surgery in the United States, contributing significantly to health care-associated patient morbidity, death, and costs [1–4]. With an estimated 27 million surgical procedures each year, and a 2–5% rate of SSIs, approximately 300,000–500,000 SSI can be predicted to occur annually [2–6]. They are believed to increase the risk of dying 2–11 fold [7,8], with 77% of these deaths attributed directly to the infection [4]. Furthermore, a mean attributable increase of 7–10 days of postoperative hospitalization leads to higher costs, including additional annual health care expenditures ranging from $1–10 billion [5,7–11].

Before the mid-19th Century, the majority of surgical patients developed SSI. The process began with an "irritative fever," followed by purulent drainage from the incision as well as sepsis and death. The face of surgery changed radically when Joseph Lister, in the late 1860s, introduced the principles of antisepsis, decreasing patient suffering by reducing postoperative infectious morbidity substantially [4]. Since then, advances in surgical techniques, including better hemostasis, conservation of an adequate blood supply, hypothermia prevention, atraumatic tissue handling, and infection control practices such as better operating room ventilation, sterilization methods, and the use of antimicrobial prophylaxis, have continued to decrease SSI [1,4,12]. However, SSI remain a substantial cause of morbidity and death, possibly because of the emergence of antibiotic-resistant micro-organisms, larger numbers of elderly surgical patients or those with a variety of chronic and immunocompromising conditions, and greater use of prosthetic implants and organ transplantation [4].

Microbial contamination of the surgical site leads to SSI that can be classified as either incisional or organ/space [4,13]. Incisional SSI are divided into *superficial*, involving only the skin and subcutaneous tissues; and *deep*, involving deeper soft tissues (Fig. 1). Organ/space SSIs can involve any part of the anatomy excluding the incised body wall layers (i.e., intra-abdominal abscess) [4]. Quantitatively, $>10^5$ microorganisms/g of tissue is defined as surgical site contamination, significantly increasing the risk of SSI [13]. On the other hand, a much smaller inoculum of contaminating microorganisms is

Division of Trauma and Surgical Critical Care, Department of Surgery, University of Virginia, Charlottesville, Virginia.
Presented at the 29th Annual Meeting of the Surgical Infection Society, Chicago, Illinois, May 6–9, 2009.

FIG. 1. The enemy. Seventy-eight year old woman six days after left above-knee amputation for acute lower-extremity ischemia presented with superficial surgical site infection. Photograph shows areas of erythema, necrosis, and epidemolysis at the incision site.

required to produce infection when foreign material is present at the site. For example, only 100 staphylococci/g of tissue are needed to increase the risk of SSI when introduced on a silk suture [14–16]. For most SSI, the pathogens originate from the endogenous flora (e.g., patient's skin, hollow viscera). However, surgical personnel, the operating room environment, surgical instruments, and many other exogenous sources contribute to these serious infections.

This article should provide the reader with a broad, but not comprehensive, overview of the literature and our own opinion on the most practical ways to avoid SSI. The goal is to present a concise review of some of the most important prevention measures that should be considered in all surgical patients.

Approaches

Many processes that can reduce the incidence of SSI have been underutilized in practice, despite a large body of evidence suggesting their efficacy [17]. In 2002, the National Surgical Infection Prevention (SIP) Collaborative was sponsored by the Centers for Medicare and Medicaid Services with the aim of reducing the nationwide incidence of SSI through systemic-level protocol implementation [18]. Fifty-six hospitals agreed to participate in this one-year demonstration project by improving such elements as antibiotic selection; timing of antibiotic administration, duration of operations; maintenance of normothermia, oxygenation, euglycemia; and hair removal. These preventive measures have since been adopted as part of the larger Surgical Care Improvement Project (SCIP). Dellinger et al. [17] showed a significant decrease in overall surgical infections, from 2.3% to 1.7% ($p = 0.0005$), with the above mentioned measures. More recently, Hedrick et al. [18] showed that the incidence of SSI decreased from 25.6% to 15.9% ($p \leq 0.05$) with additional improvements in the hospital length of stay after these measures were adopted. The following sections describe in detail many potential preventive measures that can be undertaken to decrease SSI.

Preoperative preparation

Chlorhexidine shower

Several studies have evaluated the effect of preoperative whole-body washing with chlorhexidine detergent on the incidence of postoperative incisional infections. Hayek et al. [19] assessed 1,989 patients in a placebo-controlled trial, where 24 h prior to an operation, patients were instructed to bathe twice with chlorhexidine, bar soap, or placebo. The overall infection rate for patients having chlorhexidine treatment was 9% compared with 12.8% for bar soap and 11.7% for placebo. In clean cases specifically, SSI were reduced even further: 7.2% for chlorhexidine, 10.2% for bar soap, and 10% for placebo. Chlorhexidine is believed to reduce bacterial colony counts nine-fold compared with other cleaning measures [19]. It is a simple, easy, and cheap intervention, which, if nothing else, involves patients in their medical care. Although preoperative showers have never been proved to reduce SSI rates, they are likely not hazardous, and we encourage their use in surgical patients.

Preoperative antibiotics

"Surgical antimicrobial prophylaxis" refers to a brief course of an antimicrobial agent initiated before an operation [21–28]. Its purpose is to reduce the microbial burden of intraoperative contamination to a level that should not overwhelm host defenses. The administration of preoperative antibiotics has become a part of routine operating room protocols. The use of antibiotics for appropriate cases (usually clean-contaminated, dirty, or clean cases where prosthetic material is implanted) makes intuitive sense and is easy and inexpensive, and several publications have reported its benefits.

One related area of research concerns the appropriate dosing of prophylactic antibiotics. Forse et al. [29], in a randomized controlled study, compared SSI rates of morbidly obese patients undergoing gastroplasty and normal-weight patients undergoing clean-contaminated procedures. This two-part study found that the use of appropriate cefazolin doses decreases SSI rates dramatically. Morbidly obese patients had a dramatic decrease in SSI rates, from 16.5% to 5.6% ($p < 0.03$), when the dose of cefazolin was increased to ensure adequate tissue concentrations. On the basis of this study as well as several others, the use of antibiotics on induction of anesthesia has become the standard of care.

Cephalosporins are the most thoroughly studied perioperative antimicrobial agents [30], effective against many gram-positive and gram-negative microorganisms, safe, and reasonably priced [31]. Cefazolin provides adequate coverage for many clean-contaminated operations [32,33], although a second-generation cephalosporin with adequate anaerobic coverage (e.g., cefoxitin) should be used in operations involving the distal intestinal tract. Other consideration regarding specific choices for surgical antimicrobial agents are beyond the scope of this paper.

Resistant organisms

Whether vancomycin, as a prophylactic antibiotic, should be used routinely has been addressed by several studies. Although it may be the antibiotic of choice in patients with an allergy to cephalosporins, routine use is not recommended unless there is a very high risk of methicillin-resistant *Staphylococcus aureus* (MRSA). Disturbingly, Anderson et al. [1] found that MRSA, followed by methicillin-sensitive *S. aureus* (MSSA), were the pathogens most commonly recovered after surgical procedures in certain areas. The prevalence rate of MRSA-associated SSI almost doubled during their study period, from 0.12 to 0.23 infections per 100 procedures ($p < 0.0001$). These infections, as reported by Engemann et al. [8], led to a higher 90-day mortality rate, longer hospitalization after diagnosis of infection, and higher hospital charges, initiating the idea that vancomycin could be a beneficial perioperative antibiotic. However, Finkelstein et al. [37], in a randomized controlled trial, found no significant difference in efficacy between vancomycin and cefazolin prophylaxis in preventing SSI in tertiary medical centers with high MRSA prevalence. Because vancomycin requires longer infusion times and is outside the usual operating room protocols with inconclusive data in favor of its use, we suggest continued use of cefazolin with discontinuation 24 h post-procedure unless there is an extraordinarily high risk of MRSA infection.

Timing of antibiotics

The initial dose of prophylactic antibiotics should be timed so that an inhibitory concentration of the drug is established in the serum and tissues by the time the skin is incised [4,38]. Because most prophylactic antibiotics exhibit time-dependent bactericidal action, the proper timing of antibiotics in relation to surgical incision is of utmost importance [4]. Classen et al. [38] evaluated this question prospectively in patients undergoing elective clean or clean-contaminated procedures. Surgical site infection rates were significantly lower in patients whose perioperative antibiotics were administered within 2 h of the incision (1.4%) compared with 3.3% in those with postoperative (3–24 h post-procedure) administration and 3.8% in those having preoperative (2–24 h before the procedure) administration. In view of this evidence, perioperative antibiotics should be administered as close to the incision time as possible. Additionally, in order to maximize the benefit of prophylactic antibiotics, therapeutic concentrations of the drug should be maintained throughout the procedure as well as for several hours after the incision is closed [30,32,34,39–42]. This would require antibiotic redosing at 3-h intervals for cefazolin, for example [43].

Operating room conduct

Hair removal

Shaving of the operative sites has been well established since the beginning of the 20th Century, when it seemed that removal of hair would improve wound healing. This ritual has remained unchallenged until recently, when people suggested that bacteria proliferate in the nicks and cuts in the damaged skin surface after shaving [44]. In fact, shaving of the surgical site the night before is associated with significantly higher SSI risks than no hair removal or use of depilatory creams [45–50]. Preoperative hair removal is unlikely to cease, however, as hair often interferes during the operation.

Alexander et al. [51] compared the influence of shaving and clipping on the incidence of SSI in patients undergoing elective operations at a single hospital. Patients were randomized to clippers or razors the night before or the morning of the procedure. The highest rates of infection (5.2%–6.4% at discharge) were seen with the use of a razor regardless of the timing. This was followed by the use of a clipper the night before (4%), but the best results were reported when the hair was clipped just before the procedure (1.8% SSI at discharge). Regardless of the fact that some studies have shown that preoperative hair removal by any means is associated with higher SSI rates [46,52,53], clippers should be utilized immediately prior to the operation if hair removal is needed.

Skin preparation

Several antiseptic agents are available for preoperative preparation of the skin at the incision site, including

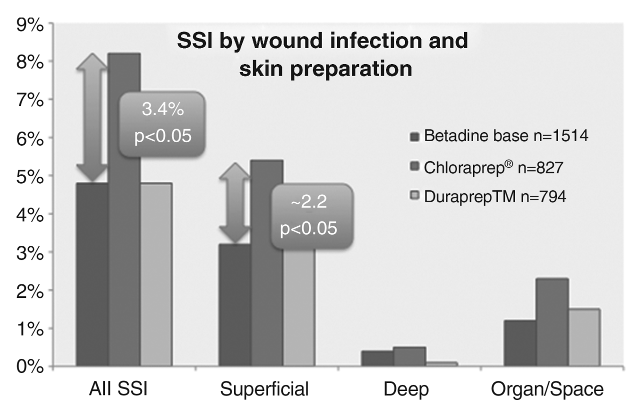

FIG. 2. Differences in surgical site infection rates in general surgery patients according to type of skin preparation used over an 18-month period at the University of Virginia.

iodophors, alcohol-containing products, and chlorhexidine gluconate. However, no studies have compared the effects of these skin antiseptics on the SSI risk adequately [4]. Swenson et al. [54] performed a prospective study using three antiseptics for a 6-month period for all general surgery cases. The skin was prepared using povidone–iodine scrub-paint combination with isopropyl alcohol used in between, Chloraprep® (2% chlorhexidine with 70% isopropyl alcohol), or Duraprep® (iodine povacrylex in isopropyl alcohol). Lower SSI rates were seen with Duraprep® (3.9%) than with Chloraprep® (7.1%) or povidone-iodine (6.4%)(Fig. 2). Clearly, additional studies are needed with only this weak evidence favoring the use of iodine-based antiseptics.

Hyperglycemia

Perioperative hyperglycemia has been associated with a higher incidence of SSI in patients undergoing cardiac surgery. More specifically, hyperglycemia during the immediate postoperative period was an independent risk factor for infections among patients with the risk of infection correlating with the degree of glucose elevation. Similarly, better glucose control has been associated with a decrease in SSI in the same population [55–57]. Although the contribution of diabetes mellitus to SSI risk is still controversial [4], euglycemia probably should be maintained perioperatively in surgical patients, although to what degree continues to be debated.

Blood transfusions

Perioperative transfusion of leukocyte-containing allogenic components has been suggested as a risk factor for the development of SSIs, with leukocyte-reduced blood imposing a much lower risk [43,58,59]. In 2006, Madbouly et al. [68] reported a significantly higher overall infection rate (48.75% vs. 11.22%; $p < 0.001$) as well as SSI risk (18.2% vs. 2.8%; $p < 0.05$) in one transfused patient group. However, there currently is no scientific basis for withholding necessary blood products from anemic surgical patients, although the use of leukocyte-reduced blood may be beneficial.

Intraoperative hypothermia

Hypothermia, through vasoconstriction and impaired immunity, may increase patients' risks of SSI [60,61]. Vasoconstriction is believed to decrease the partial pressure of oxygen in tissues, lowering resistance to infection in animals [62,63] and probably humans, whereas immune system impairment results in decreased chemotaxis, phagocytosis, and production of antibiodies. Kurz et al. [64] were able to show that intraoperative hypothermia was associated with a 13% increase in infections compared to patients who were warmed to normothermia. A small difference in temperature, 2°C, resulted in an almost tripled incidence of infection and prolonged hospital stay, demonstrating the importance of maintenance of core temperatures intraoperatively.

Postoperative wound care: Incision closure and coverage

Several studies have suggested a lower risk of SSI with the use of antimicrobial-coated sutures. Fleck et al. [65] evaluated sternal infections after cardiac surgery and found that the use of Triclosan-coated suture material greatly reduced both superficial and deep infections. After primary closure, incision sites usually are covered with a sterile dressing for 24–48 h in order to allow formation of a scab between the approximated skin edges [66,67]. Recently, however, Silvestri et al. [12] showed that application of a tissue adhesive may further reduce the onset of SSI. Application of 2-octyl-cyanoacrylate was an effective barrier in vitro studies and reduced SSI significantly (odds ratio 4.57) compared with the use of a sterile dressing alone.

Conclusions

We have reviewed several important preventive measures that can be performed easily to reduce the risk of SSI, as well as patient morbidity, mortality rate, and healthcare costs. Although many of these interventions have modest supporting data, from a pragmatic standpoint, surgeons do need to choose what protocols to follow, and we have given an overview of our current practice.

Administration, timing, and appropriate type and dosing of antimicrobials are likely some of the most critical factors in preventing postoperative infections. These efforts may be combined with the maintenance of normothermia and euglycemia and the SCIP measures as part of the standard surgical protocols in order to decrease the risk of SSI further. On the other hand, shaving with razors and misuse of antimicrobials will certainly increase patients' risk for SSI and antimicrobial resistance. Although still unproved, the use of different skin antiseptics, antimicrobial-coated sutures, and tissue adhesives shows promise in further reducing the risk of SSI.

Beyond the apparently simple task of utilizing these preventive measures, the path to improvement must include physicians collaborating with each other, communicating with their operating room staff/teams, and creating protocols that can be followed easily and be consistent among surgeons. Involving other departments such as pharmacy may additionally prevent errors and make the administration of appropriate medications automatic. Hospitals accepting membership in SCIP may provide strong incentives for standardization of protocols, where quality can be assessed and enhanced easily by evaluating overall outcomes as well as the fractions of patients who receive appropriate preventive measures. The key to improvement lies in the surgeons' consistency, involvement, and leadership as additional reductions in SSI are achieved.

Author Disclosure Statement

Dr. Sawyer has received research funding from and consulted for 3M and ETHICON.

References

1. Anderson DJ, Sexton, DJ, Kanafani ZA, et al. Severe surgical site infection in community hospitals: Epidemiology, key procedures, and the changing prevalence of methicillin-resistant *Staphylococcus aureus*. Infect Control Hosp Epidemiol 2007;28:1047–1053.
2. Graves EJ; National Center for Health Statistics. National Hospital Discharge Survey: Annual Summary, 1987. Series 13, no. 99. Hyattsville, MD: Department of Health and Human Services Publication (PHS) 89-1760. 1989. Available

at www.cdc.gov/nchs/products/pubs/pubd/series/sr13/100-1/100-1.htm
3. National Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004. Am J Infect Control 2004;32:470–485.
4. Mangram AJ, Horan TC, Pearson ML, et al. Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee. Infect Control Hosp Epidemiol 1999;20:250–278.
5. Cruse P. Wound infection surveillance. Rev Infect Dis 1981;3:734–737.
6. Surgical Site Infections (SSI). Atlanta, GA: Centers for Disease Control and Prevention [updated December 18, 2008; cited Nov 1, 2009]. Available at www.cdc.gov/ncidod/dhqp/FAQ_SSI.html
7. Kirkland KB, Briggs JP, Trivette SL, et al. The impact of surgical-site infections in the 1990s: Attributable mortality, excess length of hospitalization, and extra costs. Infect Control Hosp Epidemiol 1999; 20:725–730.
8. Engemann JJ, Carmeli Y, Cosgrove SE, et al. Adverse clinical and economic outcomes attributable to methicillin resistance among patients with *Staphylococcus aureus* surgical site infection. Clin Infect Dis 2003;36:592–598.
9. Martone WJ, Nichols RL. Recognition, prevention, surveillance, and management of surgical site infections: Introduction to the problem and symposium overview. Clin Infect Dis 2001;33(Suppl 2):S67–S68.
10. Cruse PJ, Foord R. The epidemiology of wound infection: A 10-year prospective study of 62,939 wounds. Surg Clin North Am 1980;60:27–40.
11. Wong ES. Surgical Site Infections. 3rd edition. Baltimore: Lippincott, Williams & Wilkins. 2004.
12. Silvestri A, Brandi C, Grimaldi L, et al. Octyl-2-cyanoacrylate adhesive for skin closure and prevention of infection in plastic surgery. Aesthet Plast Surg 2006;30:695–699.
13. Krizek TJ, Robson MC. Evolution of quantitative bacteriology in wound management. Am J Surg 1975;130:579–584.
14. Elek SD, Conen PE. The virulence of *Staphylococcus pyogenes* for man: A study of problems with wound infection. Br J Exp Pathol 1957;38:573–586.
15. Noble WC. The production of subcutaneous staphylococcal skin lesions in mice. Br J Exp Pathol 1965;46:254–262.
16. James RC, MacLeod CJ. Induction of staphylococcal infections in mice with small inocula introduced on sutures. Br J Exp Pathol 1961;42:266–277.
17. Dellinger EP, Hausmann SM, Bratzler DW, et al. Hospitals collaborate to decrease surgical site infections. Am J Surg 2005;190:9–15.
18. Hedrick TL, Heckman JA, Smith RL, et al. Efficacy of protocol implementation on incidence of wound infection in colorectal operations. J Am Coll Surg 2007;205:432–438.
19. Hayek LJ, Emerson JM, Gardner AM. A placebo-controlled trial of the effect of two preoperative baths or showers with chlorhexidine detergent on postoperative wound infection rates. J Hosp Infect 1987;10:165–172.
20. Paulson DS. Efficacy evaluation of a 4% chlorhexidine gluconate as a full-body shower wash. Am J Infect Control 1993;21:205–209.
21. Nichols RL, Holmes JW. Prophylaxis in bowel surgery. Curr Clin Top Infect Dis 1995;15:76–96.
22. Nichols RL, Smith JW, Muzik AC, et al. Preventive antibiotic usage in traumatic thoracic injuries requiring closed tube thoracostomy. Chest 1994;106:1493–1498.
23. Bullock R, van Dellen JR, Ketelbey W, Reinach SG. A double-blind placebo controlled trial of perioperative prophylactic antibiotics for elective neurosurgery. J Neurosurg 1988;69:687–691.
24. Page CP, Bohnen JM, Fletcher JR, et al. Antimicrobial prophylaxis for surgical wounds: Guidelines for clinical care. Arch Surg 1993;128:79–88.
25. Targarona EM, Garau J, Munoz-Ramos C, et al. Single-dose antibiotic prophylaxis in patients at high risk for infection in biliary surgery: A prospective and randomized study comparing cefonicid with mezlocillin. Surgery 1990;107:327–334.
26. van Ek B, Dijkmans BA, van Dulken H, van Furth R. Antibiotic prophylaxis in craniotomy: A prospective double-blind placebo controlled study. Scand J Infect Dis 1988;20:633–639.
27. Platt R. Guidelines for perioperative antibiotic prophylaxis. In: Abrutyn E, Goldmann DA, Scheckler WE (eds): Saunders Infection Control Reference Service. Philadelphia: WB Saunders. 1997:229–234.
28. Sanderson PJ. Antimicrobial prophylaxis in surgery: Microbiological factors. J Antimicrob Chemother 1993;31(Suppl B):1–9.
29. Forse RA, Karam B, MacLean LD, Christou NV. Antibiotic prophylaxis for surgery in morbidly obese patients. Surgery 1989;106:750–756.
30. Nichols RL. Surgical antibiotic prophylaxis. Med Clin North Am 1995;79:509–522.
31. Page CP, Bohnen JM, Fletcher JR, et al. Antimicrobial prophylaxis for surgical wounds: Guidelines for clinical care. Arch Surg 1993;128:79–88.
32. Nichols RL. Antibiotic prophylaxis in surgery. J Chemother 1989;1:170–178.
33. Bumpous JM, Johnson JT. The infected wound and its management. Otolaryngol Clin North Am 1995;28:987–1001.
34. Anonymous. Antimicrobial prophylaxis in surgery. Med Lett Drugs Ther 1997;39:97–102.
35. Ehrenkranz NJ, Meakins JL. Surgical infections. In: Bennett JV, Brachman PS (eds): Hospital Infections. 3rd edition. Boston: Little, Brown. 1992:685–710.
36. Hospital Infection Control Practices Advisory Committee. Recommendations for preventing the spread of vancomycin resistance. Infect Control Hosp Epidemiol 1995;16:105–113.
37. Finkelstein R, Rabino G, Mashiah T, et al. Vancomycin versus cefazolin prophylaxis for cardiac surgery in the setting of a high prevalence of methicillin-resistant staphylococcal infections. J Thorac Cardiovasc Surg 2002;123:326–332.
38. Classen DC, Evans RS, Pestotnik SL, et al. The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection. N Engl J Med 1992;326:281–286.
39. Mayhall CG. Surgical infections including burns. In: Wenzel RP (ed): Prevention and Control of Nosocomial Infections. 2nd edition. Baltimore: Williams & Wilkins. 1993:614–664.
40. Scher KS. Studies on the duration of antibiotic administration for surgical prophylaxis. Am Surg 1997;63:59–62.
41. Trilla A, Mensa J. Perioperative antibiotic prophylaxis. In: Wenzel RP (ed): Prevention and Control of Nosocomial Infections. 2nd edition. Baltimore: Williams & Wilkins. 1993:665–682.
42. McDonald M, Grabsch E, Marshall C, Forbes A. Single-versus multiple-dose antimicrobial prophylaxis for major surgery: A systematic review. Aust N Z J Surg 1998;68:388–396.

43. Campbell DA Jr, Henderson WG, Englesbe MJ, et al. Surgical site infection prevention: The importance of operative duration and blood transfusion—Results of the first American College of Surgeons–National Surgical Quality Improvement Program Best Practices Initiative. J Am Coll Surg 2008;207:810–820.
44. Garner JS, Emori TG, Haley RW. Operating room practices for the control of infection in U.S. hospitals, October 1976 to July 1977. Surg Gynecol Obstet 1982;155:873–880.
45. Cruse PJ, Foord R. The epidemiology of wound infection: A 10-year prospective study of 62,939 wounds. Surg Clin North Am 1980;60:27–40.
46. Mishriki SF, Law DJ, Jeffery PJ. Factors affecting the incidence of postoperative wound infection. J Hosp Infect 1990;16:223–230.
47. Seropian R, Reynolds BM. Wound infections after preoperative depilatory versus razor preparation. Am J Surg 1971; 121:251–254.
48. Hamilton HW, Hamilton KR, Lone FJ. Preoperative hair removal. Can J Surg 1977;20:269–271, 274–275.
49. Olson MM, MacCallum J, McQuarrie DG. Preoperative hair removal with clippers does not increase infection rate in clean surgical wounds. Surg Gynecol Obstet 1986;162:181–182.
50. Mehta G, Prakash B, Karmoker S. Computer assisted analysis of wound infection in neurosurgery. J Hosp Infect 1988;11:244–252.
51. Alexander JW, Fischer JE, Boyajian M, et al. The influence of hair-removal methods on wound infections. Arch Surg 1983; 118:347–352.
52. Moro ML, Carrieri MP, Tozzi AE, et al. Risk factors for surgical wound infections in clean surgery: A multicenter study. Italian PRINOS Study Group. Ann Ital Chir 1996;67: 13–19.
53. Winston KR. Hair and neurosurgery. Neurosurgery 1992; 31:320–329.
54. Swenson BR, Hedrick TL, Metzger R, et al. Effects of preoperative skin preparation on postoperative wound infection rates: A prospective study of 3 skin preparation protocols. Infect Control Hosp Epidemiol 2009;30:964–971.
55. Latham R, Lancaster AD, Covington JF, et al. The association of diabetes and glucose control with surgical-site infections among cardiothoracic surgery patients. Infect Control Hosp Epidemiol 2001;22:607–612.
56. Glucose control lowers the risk of wound infection in diabetics after open heart operations. Ann Thorac Surg 1997;63:356–361.
57. Furnary A, Zerr K, Grunkemeier G, Starr A. Continuous intravenous insulin infusion reduces the incidence of deep sternal wound infection in diabetic patients after cardiac surgical procedures. Ann Thorac Surg 1999;67:352–362.
58. Van de Watering LM, Hermans J, Houbiers JG, et al. Beneficial effects of leukocyte depletion of transfused blood on postoperative complications in patients undergoing cardiac surgery: A randomized clinical trial. Circulation 1998;97: 562–568.
59. Houbiers JG, Brand A, van de Watering LM, et al. Randomised controlled trial comparing transfusion of leucocyte-depleted or buffy-coat-depleted blood in surgery for colorectal cancer. Lancet 1994;344:573–578.
60. Ozaki M, Sessler DI, Suzuki H, et al. Nitrous oxide decreases the threshold for vasoconstriction less than sevoflurane or isoflurane. Anesth Analg 1995;80:1212–1216.
61. Sessler DI, Rubinstein EH, Moayeri A. Physiologic responses to mild peri-anesthetic hypothermia in humans. Anesthesiology 1991;75:594–610.
62. Chang N, Mathes SJ. Comparison of the effect of bacterial inoculation in musculocutaneous and random-pattern flaps. Plast Reconstr Surg 1982;70:1–10.
63. Jönsson K, Hunt TK, Mathes SJ. Oxygen as an isolated variable influences resistance to infection. Ann Surg 1988; 208:783–787.
64. Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of Wound Infection and Temperature Group. N Engl J Med 1996;334:1209–1215.
65. Fleck T, Moidl R, Blacky A, et al. Triclosan-coated sutures for the reduction of sternal wound infections: Economic considerations. Ann Thorac Surg 2007;84:232–236.
66. DuMortier JJ. The resistance of healing wounds to infection. Surg Gynecol Obstet 1933;56:762–766.
67. Morain WD, Colen LB. Wound healing in diabetes mellitus. Clin Plast Surg 1990;17:493–501.
68. Madbouly KM, Senagore AJ, Remzi FH, et al. Perioperative blood transfusions increase infectious complications after ileoanal pouch procedures (IPAA). Int J Colorectal Dis 2006;21:807–813.

Address correspondence to:
Dr. Robert G. Sawyer
Department of Surgery
University of Virginia Health System
P.O. Box 800709
Charlottesville, VA 22908

E-mail: rws2k@virginia.edu